A REPORT TO THE

SAN FRANCISCO CITY-STATE JOINT FREEWAY STUDY

ON THE TUNNEL CONSTRUCTION ASSOCIATED WITH

THE PANHANDLE AND GOLDEN GATE FREEWAYS

FEBRUARY 1966

APPENDIX 7

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PREPARED BY
JACOBS ASSOCIATES
FEBRUARY 1966

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A REPORT TO THE SAN FRANCISCO CITY-STATE JOINT FREEWAY STUDY ON THE TUNNEL CONSTRUCTION ASSOCIATED WITH THE PANHANDLE AND GOLDEN GATE FREEWAYS

Prepared By

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JACOBS ASSOCIATES ENGINEERS AND CONSULTANTS
CONSTRUCTION PERFORMANCE SERVICES
500 SANSOME • SAN FRANCISCO 94111 • TELEPHONE (415) 434-1822 • CABLE: DONJAY

February 7, 1966

Mr. Thomas J. Mellon
Chief Administrative Officer of San Francisco
289 City Hall
San Francisco, California

Dear Mr. Mellon:

On December 23, 1965, you first discussed with us several construction problems which confront the City of San Francisco relative to the proposed extensions to its freeway system. Subsequent to that conference we received an assignment from the City to investigate the practicability of constructing certain stretches of the freeway underground by utilizing tunnel driving methods.

Your Directors have also asked that we review and express an opinion regarding the Aquatic Freeway, a scheme which has been proposed by an independent engineering organization.

We are pleased to present this report containing the information compiled during the five weeks of our investigation, together with the conclusions reached after having made those studies.

Much credit for completion of this study within the allocated time must be given to Mr. Ross T. Shoaf, Assistant City Engineer, who has so ably coordinated the efforts of the consulting team. City Engineer, Mr. Clifford J. Geertz, and his department, as well as the officers and staff of the State Division of Highways, have also cooperated to the fullest extent in this effort. We wish to express our appreciation to these people for their help and to thank the City of San Francisco for giving us an opportunity to assist in this important effort.

Sincerely yours,

JACOBS ASSOCIATES,

/s/ Donovan Jacobs

J. Donovan Jacobs

JDJ:slf

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FOREWARD

The opening chapter in this report is entitled SUMMARY AND CONCLUSIONS. The five pages of manuscript which are included in this summary are merely a digest of what has been said in the remainder of the report.

If the organization of the report in this manner makes the document seem disjointed, we wish to explain that the five page condensation and the three illustrative plates which accompany it have been bound and issued as a condensed report for those who are interested only in the essential information and who do not have the time to struggle through the technical discussions which follow thereafter.

SUMMARY AND CONCLUSIONS

FILLMORE HILL TUNNEL

Exploratory earth borings indicate that rock underlies Fillmore Hill along the route of the proposed freeway from Webster Street on the east to somewhere in the vicinity of Scott Street on the west. The samples taken, however, show the rock to be of a disappointingly poor quality through which to drive large tunnels.

Even though the geological conditions are not the best, twin tunnels of the size shown in this report can be driven under Fillmore Hill, providing that proper construction engineering procedures are followed.

If tunnels of this size are to be driven through Fillmore Hill without causing an excessive amount of settlement of the ground surface above, it is essential that the Engineer maintain strict control over the Contractor's method of construction.

The length of tunnels which can be practicably driven is approximately 1715 feet, including portal and terminal structures. The bores would extend from the east side of Webster Street to approximately 160 feet west of Pierce Street where they will join a cut-and-cover tunnel structure extending westward toward the Panhandle. The tunnels will be parallel, on the same level, and 126 feet apart, center to center.

The estimated contract cost of constructing these tunnels, if awarded today, is $26,982,000.

Tunnelling through the Hill would also result in an increased cost for a portion of the cut-and-cover section which joins the end of the tunnel. This is because the lower roadway level of the

tunnel necessitates the digging of a deeper trench for the easterly portion of the cut-and-cover stretch.

Construction can be completed in approximately forty-four months from the time the contract is awarded.

Illustration and description of a proposed method for construction of Fillmore Hill Tunnel is included in this report.

STANYAN HILL TUNNEL

The maximum length of tunnel which could practicably be driven at this location is approximately 1200 feet.

Test borings indicate that for half of this distance the material to be encountered would be predominantly sand and soil, with no rock. For the remaining distance it is probable that most of the twin tunnel faces would be partly sand and partly rock.

Because the problem of ground subsidence above the tunnel will not be as serious at Fillmore Hill, less expensive tunnel driving methods may be utilized. The presence of sand throughout most of the tunnel length suggests the possibility of successful utilization of shield methods.

Time has not been available to make a detailed cost estimate of a Stanyan Tunnel. The unit cost, however, should not exceed 65% to 85% of the cost which we have estimated for Fillmore Tunnel. This would indicate the cost of a Stanyan Tunnel to be between $5,100 and $6,700 a foot of bore.

Even though tunnelling through Stanyan Hill may cost less than through Fillmore Hill, we believe

that underground excavation will prove to be less desirable than cut-and-cover method of construction. Since there are no problems of property values and human displacement, the issue can be resolved by comparative estimates which would take into account the cost of moving and replacing existing greenery.

HYDE STREET TUNNEL

No exploratory borings were made in the vicinity of Hyde and Bay Streets.

It is our opinion that the construction of a driven tunnel across the Hyde Street Hill along Bay Street will be impractical because of the low ground cover which will overlie the tunnel arch.

AQUATIC FREEWAY PROPOSAL

The principle of precasting concrete tunnel sections in a dry dock, floating them to location and sinking them into position is feasible.

The unprecedented size of the proposed sections would, we believe, give rise to serious marine handling and construction problems which would tend to increase rather than decrease any estimates of cost made at this time.

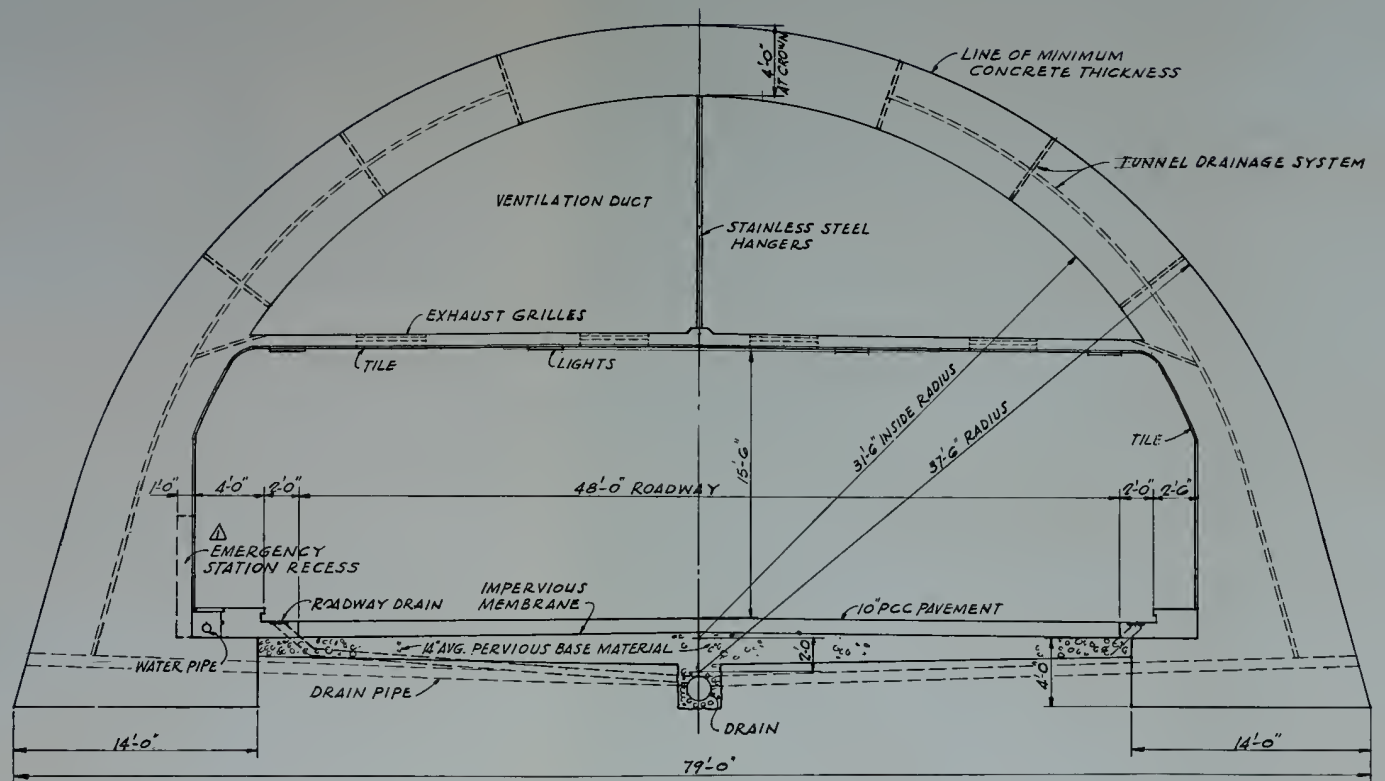
Our assessment of cost to construct the float-in-place structure is $10,000 per foot of length in place. This includes ventilation, lighting and utilities without allowance for removal or replacement of existing piers and structures.

We question the desirability of continuing the marine structure offshore between the entrance to the Yacht Harbor and the west end of Crissy Field. In our opinion, inshore right-of-way should not be a serious problem along this stretch.

If the offshore structure were to be constructed west of the Marina, the eventual result, we expect, would be the permanent filling in of that portion of the Bay between the present shoreline and the new structure.

The Aquatic scheme places the entire freeway from the Embarcadero to Golden Gate Bridge in tunnel. This is contrary to the policy to which the City and State have agreed that no more than 50% of any freeway route shall be tunnel construction.

The underwater location of the roadways will, we feel, create a psychological barrier against its use by many persons to whom the contemplation of driving for four miles through a subaqueous tunnel will forever be intolerable.



PANHANDLE FREEWAY TUNNEL SECTION

PLATE 1

DESCRIPTION	BY	CK.	APP.	DATE
Re-Labeled "Access to Recess"	JF			7-66

DESCRIPTION	BY	CK.	APP.	DATE

DRAWN BY JEF 2-4-66
CHECKED
APPROVED

JACOBS ASSOCIATES
CONSTRUCTION ENGINEERS
500 SANSOME STREET
SAN FRANCISCO CALIFORNIA

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SCALE
SERIAL NUMBER 1884
DRAWING NUMBER
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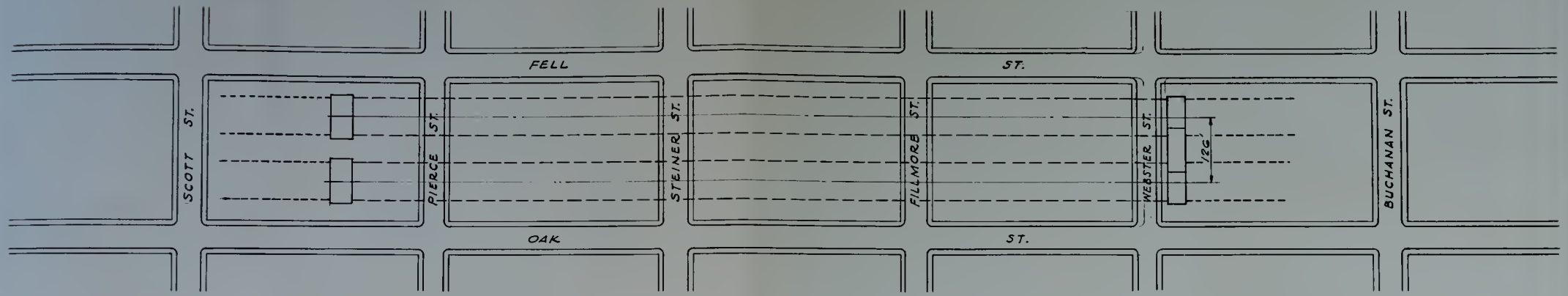
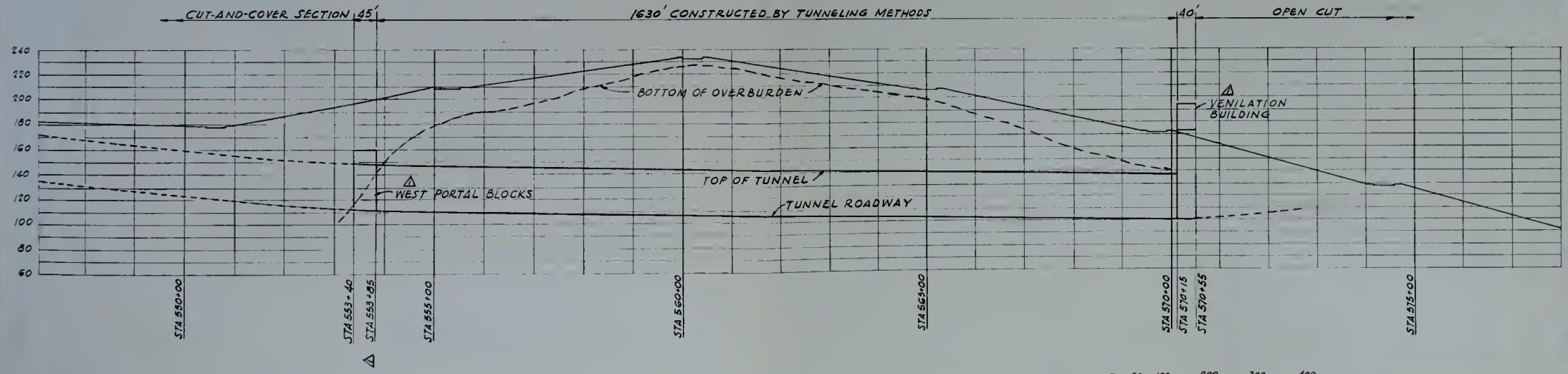
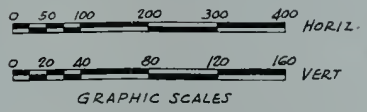


PLAN



PROFILE OF FILLMORE HILL TUNNEL



GRAPHIC SCALES

PLATE 2

DESCRIPTION	BY	CK.	APP.	DATE
2 GENERAL REVISIONS	JEF			2-66

DESCRIPTION	BY	CK.	APP.	DATE

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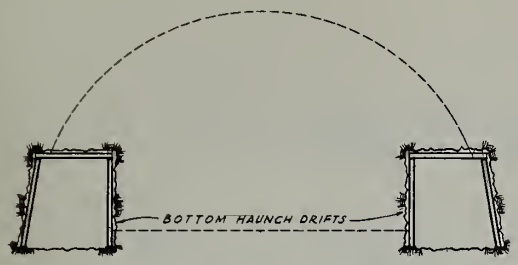
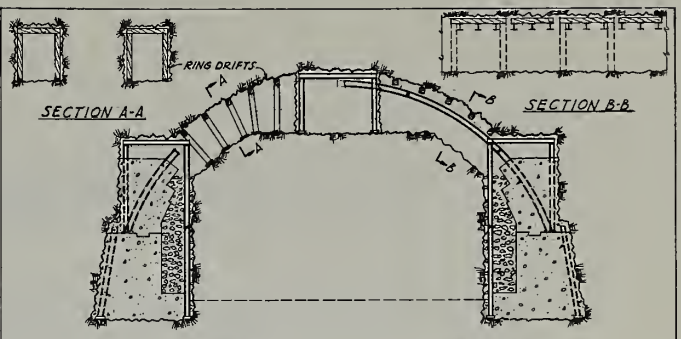
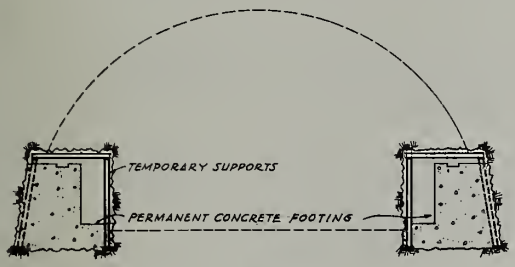


STAGE I



STAGE VI STAGE VII



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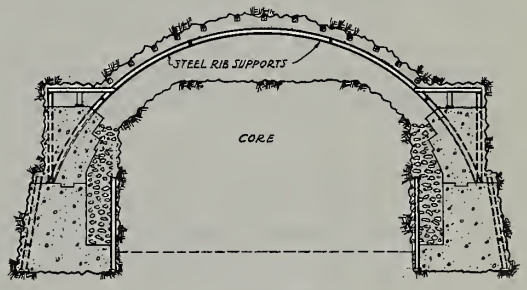

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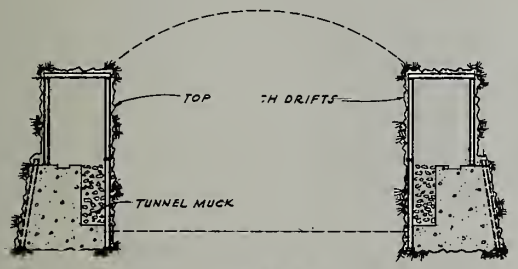
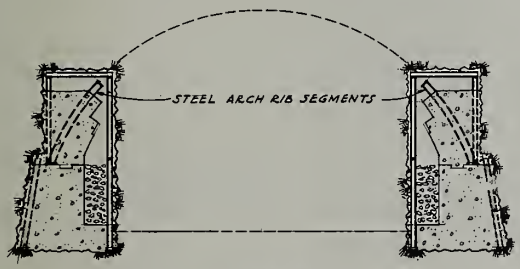
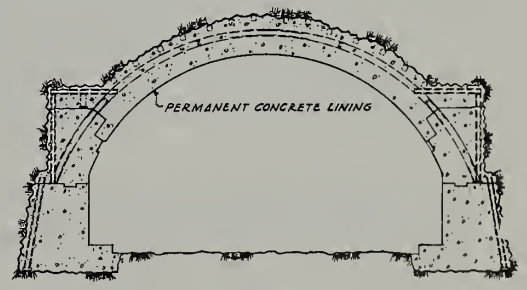


STAGE III

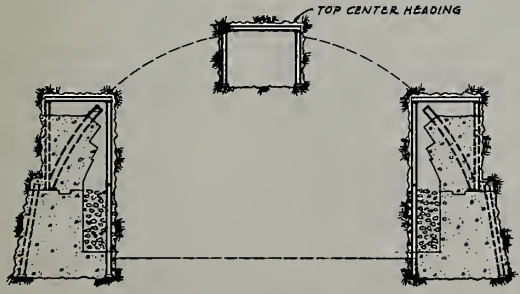
STAGE IX



STAGE IV



STAGE X



STAGE V

NOTE:
THIS DRAWING IS SCHEMATIC IN THAT SPILING, LAGGING, BLOCKING, AND OTHER MISCELLANEOUS TIMBER MEMBERS HAVE BEEN OMITTED FOR THE SAKE OF CLARITY.

PROPOSED CONSTRUCTION STAGES FOR FILLMORE HILL TUNNEL

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TUNNEL PRACTICABILITY STUDIES ~ 1966
CITY AND COUNTY OF SAN FRANCISCO

PLATE 3

EXPLANATION OF PROPOSED TUNNEL CONSTRUCTION METHOD ILLUSTRATED ON PLATE 3

STAGE I: Bottom haunch drifts are simultaneously driven for entire length of tunnel.

STAGE II: Concrete footings and lower portion of sidewall are poured within the haunch drifts.

STAGE III: Upper haunch drifts are constructed. Surplus tunnel muck drops down and compacts in the void adjacent to the concrete wall below.

STAGE IV: After installing the stub sections of steel arch supports and building forms, the next concrete lift is poured in the upper haunch drifts.

STAGE V: A top center heading is driven in the position shown for the full length of the tunnel.

STAGE VI: Working from the top center heading small "ring drifts" are excavated outward to intercept the upper haunch drifts. These wing drifts will be wide enough for two to four steel ribs and will be spaced far enough apart that the wall remaining between ribs gives adequate support to the ground above.

STAGE VII: Steel ring-beams are installed within the ring drifts, connected together first by bolting and then by welding to develop full strength of the member at the joint. If, at this stage, the ground conditions are so bad that the steel ribs appear inadequate to carry the load to be imposed upon them, forms can be placed within the ring drifts and a short section of permanent lining can be poured to imbed and supplement the steel ribs.

STAGE VIII: The walls between the ring drifts are excavated and steel ribs are continuously installed and blocked against the roof.

STAGE IX: The core of unexcavated material which remains in the center of the tunnel between the haunch drifts is excavated down to subgrade level.

STAGE X: The remainder of the concrete lining is poured.

THE ASSIGNMENT

On the 4th of January, 1966, the Director of Public Works of the City and County of San Francisco entered into an agreement with Jacobs Associates to investigate and report upon the practicability of three proposed freeway tunnels. Because the need for answers was urgent, five weeks were allotted for the completion of those studies. This report is the result of those five weeks of effort.

Basically, the assignment was to determine, in the case of each of the tunnels, whether its construction as an underground bore, using conventional methods, is economically feasible. In the event that feasibility was established the instructions were to determine maximum length, preliminary design for lining, conceptual design for a ventilation system, method of construction and estimate of cost of construction.

The tunnels to be considered were under Fillmore Hill, Stanyan Hill and Hyde Street. The contract gave specific priority to Fillmore Hill Tunnel with the stipulation that efforts were to be applied to the latter two tunnels as ordered by the Director.

GEOLOGICAL INVESTIGATIONS

Concurrently with the start of this study and to avail ourselves of needed geological advice, we requested and received approval from the City to engage the services of Mr. Roger Rhoades, consulting geologist. Mr. Rhoades, whose report is incorporated herein, has been of great help in the gathering and interpretation of information throughout this investigation. His practical approach to the problems of the constructor has helped us in development of the proposed methods for tunnelling through these particular materials.

As soon as the agreement had been concluded for the making of the study, we obtained permission from the City to seek a drilling contractor to take core samples in the regions where the proposed freeway crosses the Fillmore and Stanyan Hills. After entertaining proposals from several drilling firms a contract was awarded with the approval of the Director of Public Works to J. N. Pitcher Company to make exploratory borings, take samples and do testing where and as required and as time permitted. Inspection of the drilling and logging of the cores was capably performed by inspectors Middlebrook and Surian of the Department of Engineering. Locations of the holes drilled, logs of the holes and top of rock profiles are shown on accompanying Plate 5.

SIZE AND SHAPE OF THE TUNNEL

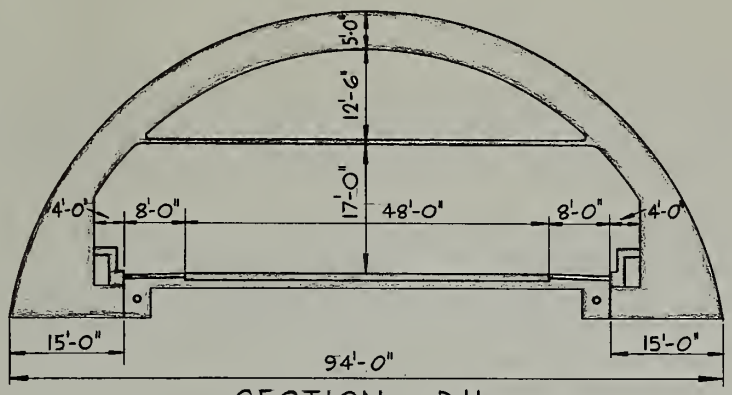
Considerable attention has been given to the selection of a shape which would best meet all the local requirements for the permanent tunnel structure. The various sections considered are shown on Plate 4.

The first section considered was the one suggested by the State Division of Highways, a sketch of which was attached to their "Preliminary Plan for Design Study Only". On Plate 4 this is identified as "Section DH". Upon checking the internal dimensions, Section DH was found to be 13.5 feet wider inside than required for a standard four-lane freeway.

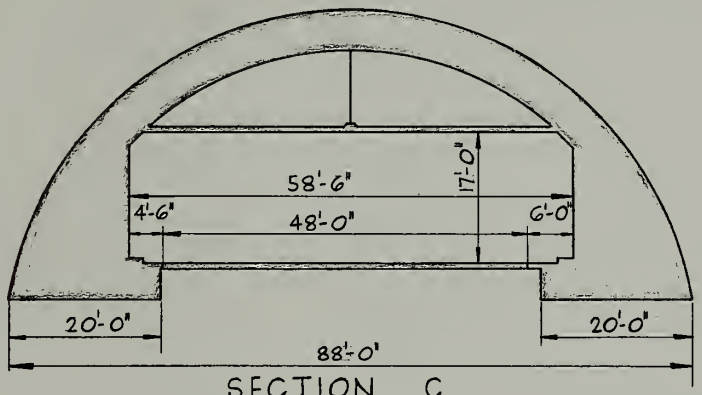
Section C was drawn in an effort to obtain a shape which closely resembles Section DH but is no wider than necessary to accommodate the four lanes of roadway. Section C, however, contained disadvantages in the form of insufficient ventilation duct space and excessive concrete volume.

Section B was suggested but was rejected after brief consideration because of its flat arch and inefficient use of concrete, as well as certain inherent construction difficulties.

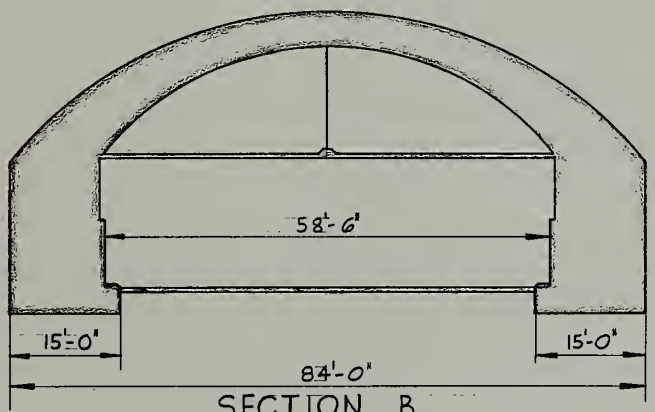
The section chosen for this study is similar to the one identified as Section A, which has the least overall width and the sharpest curvature of any of the sections considered. Attention is called to the fact that all sections on Plate A show a vertical clearance of 17 feet. Since this drawing was completed, word has been received from the Division of Highways that, instead of 17 feet vertical distance from top of finished roadway to bottom of ceiling slab, 15'-6" would be permitted on the Panhandle Freeway. Incorporating this change and making certain changes in thickness



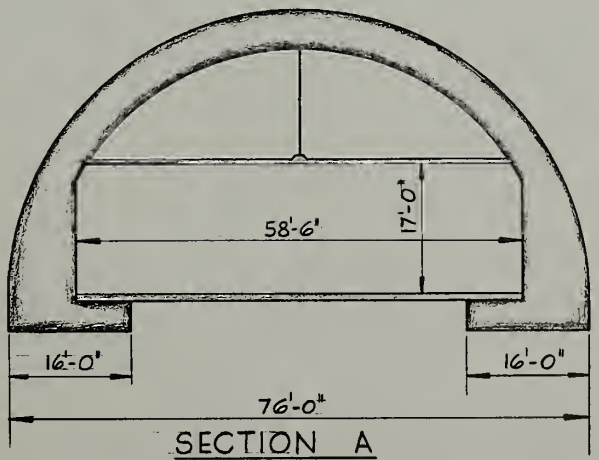
SECTION DH



SECTION C



SECTION B



SECTION A

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PLATE 4

of arch concrete after running preliminary design checks, we have arrived at the "Panhandle Freeway Tunnel Section" which is shown on Plate 1.

When twin bores are to be driven, there is always the urge to place the tunnels as closely together as possible in order to effect savings in terminal structures and approach cuts. We believe that the nature of the material in Fillmore Hill precludes close spacing of parallel bores. We recommend a center-to-center distance of the two tunnels of 126 feet, permitting a 50-foot wall of undisturbed rock between the two holes.

GROUND CONDITIONS UNDER FILLMORE HILL

A research into the history of tunnels which have been constructed through the California Coast Range reveals a long record of operations under difficult ground conditions. Unfortunately the Franciscan rock which underlies most of the City of San Francisco is one of the more troublesome of the Coast Range formations.

The borings which were made as part of this investigation confirm that the material beneath Fillmore Hill consists predominantly of Franciscan formation. A geological report by Mr. Roger Rhoades is appended hereto. One significant fact is that the borings show presence of serpentine. This mineral is a notorious hazard to underground excavation operations. Because of its weakness, its tendency to expand when exposed, and its soft, soapy texture, it frequently caves without warning and almost always is an undesirable material to be encountered in underground excavation. The borings show up the serpentine mostly in the western end of the proposed tunnel. The exploratory holes at the eastern end of the tunnel indicate the presence of a substantial amount of what may be fault-zone material within the tunnelling area. Such a situation does not indicate a desirable portal site for a four-lane vehicular tunnel.

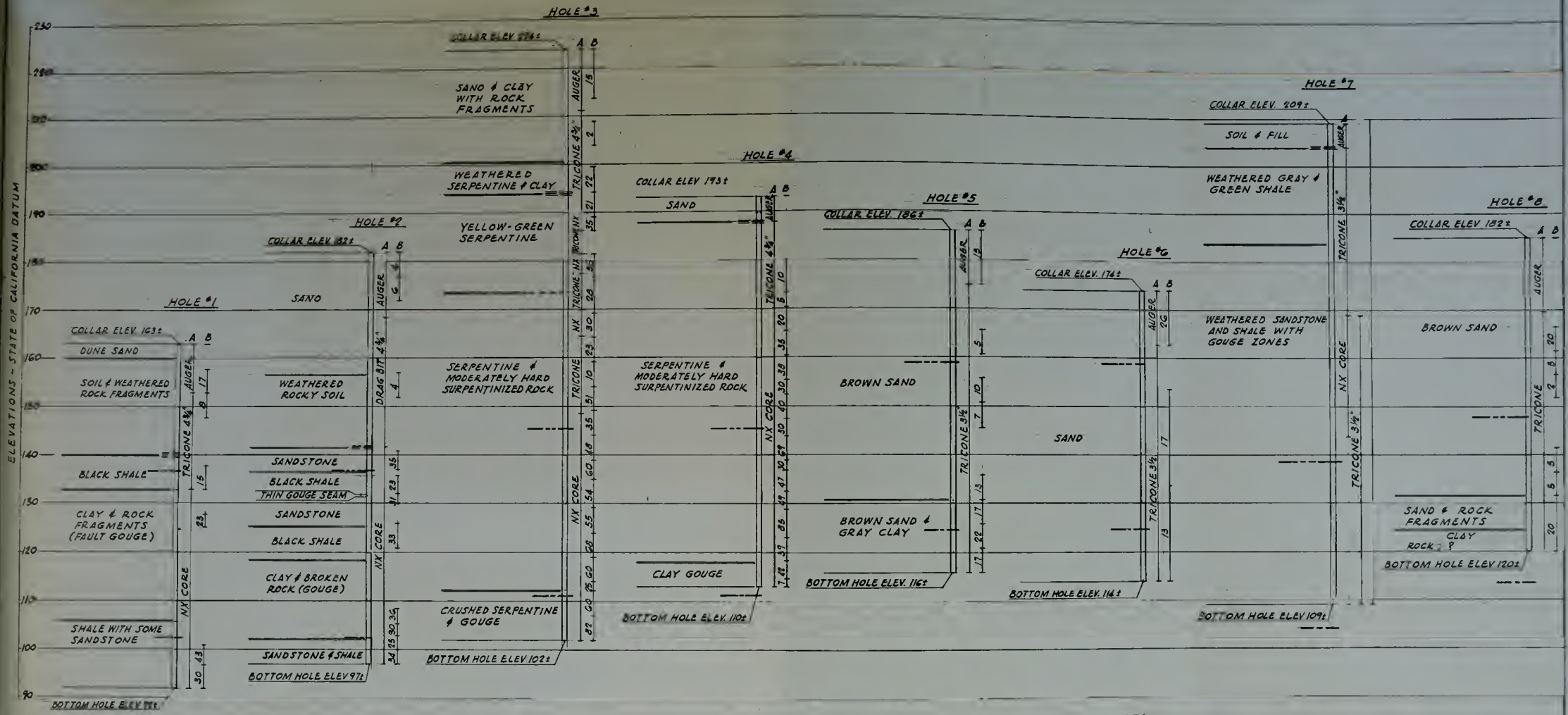
Plate 2 shows the plan and profile of a proposed pair of four-lane tunnels extending from east side of Webster Street to a terminal block approximately 160 feet west of Pierce Street for an overall length of 1715 feet. The broken line between the crown of tunnel and the ground is the bottom of over-burden. In the material encountered here, the demarcation between over-burden and rock is frequently annoyingly vague. It is significant that in this area of

doubtful tunnelling material the indications are that little protective hard cover can be expected to be encountered above the tunnel at either portal. This means that extreme care will have to be exerted in starting and concluding of tunnelling to prevent loss of ground which would cause settlement of the buildings on the surface.

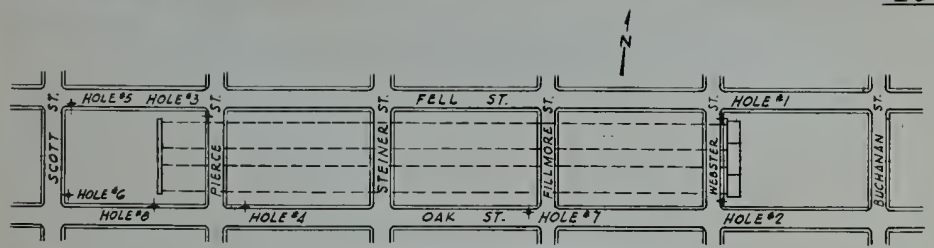
When the Stockton Street tunnel was constructed in 1915, the records reveal that a ground subsidence of several feet was experienced on the surface above the tunnel line. Fortunately there were no buildings above that tunnel in those days and the damage was limited to broken pavements, pipeline, and retaining wall. In the crowded Fillmore District today the situation is quite different. The tunnelling methods which must be used, however, have not improved markedly over the years and it would be imprudent to predict that tunnels can be driven under the Fillmore area without experiencing some settlement of ground at the surface in the vicinity of the portals. We believe that by the use of proper methods and due diligence that such subsidence can be minimized and kept within the range of two to four inches for a distance of one or two hundred feet from the face of the portal structure. This should result in only minor damage to buildings if the Contractor follows proper shoring and jacking procedures. It should not require the buildings to be vacated and should cause no danger to the occupants.

In spite of the difficult physical conditions which exist under Fillmore Hill, a pair of freeway tunnels can be driven therein providing the job is properly and carefully done. We have been asked to determine practicability of tunnelling in this location. Webster says "practicable" means "capable of being accomplished". Using that definition we do not question their practicability and submit in this report a method of construction by which we believe the desired

results may be achieved. Also included is our assessment of the cost of achieving those results. Only after the cost is revealed and compared with other alternatives can the economic feasibility be evaluated.



LOGS OF TEST BORINGS - FILLMORE HILL TUNNEL



PLAN OF BORE HOLE LOCATIONS

LEGEND

- BORE HOLES
- APPROXIMATE BOTTOM OVERBURDEN
- A - METHOD OF DRILLING
- B - DRILLING TIME IN MINUTES
- ROADWAY ELEVATION
- CROWN OF TUNNEL

DRILLING BY J.N. PITCHER CO.
DRILLING INSPECTORS
J. MIDDLEBROOK C.C.S.F
G. SURIAN C.C.S.F.
GEOLOGICAL INTERPRETATION
ROGER RHOADES

NOTE:

1. WATER TESTS CONDUCTED ON HOLES #1 AND #2. PACKERS SET 11' ABOVE BOTTOM OF HOLES. PACKERS DID NOT HOLD AT 25 PSI IN HOLE #1. NO WATER LOSS IN HOLE #2 AT 25 PSI.
2. HOLE #7 CAVED AT APPROXIMATE DEPTH OF 40'.
3. CORE RECOVERY MODERATE TO POOR.

PLATE 5

DESCRIPTION	BY	CK.	APP.	DATE

DESCRIPTION	BY	CK.	APP.	DATE

DRAWN BY JEF 2-4-66
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500 SANSOME STREET
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REV.

TUNNEL DRIVING METHOD

The geological conditions under Fillmore Hill are of such nature that they will be the deciding factor in the choice of methods to be used for constructing any underground structure in that area. If the ultimate decision is to drive tunnels beneath Fillmore Hill, we recommend that the contract documents describe and illustrate an approved construction method for driving the tunnel. The Contractor should be given an opportunity, if he chooses to do so, to submit a method of his own for consideration and approval by the Engineer. We normally support the doctrine that a contractor shall be given free scope to choose his own methods of procedure. It is to be feared, however, that if too much freedom is permitted on a difficult job such as this, one of several undesirable results might occur: An inexperienced contractor might bid the contract too low expecting to do the job by short-cut methods which get both him and the owner into trouble; or a contractor who has insufficient knowledge of the geology of the region might bid the job, expecting to perform the work by methods being used on similar tunnels elsewhere, with the result that he later comes back with an "unforseen condition" claim.

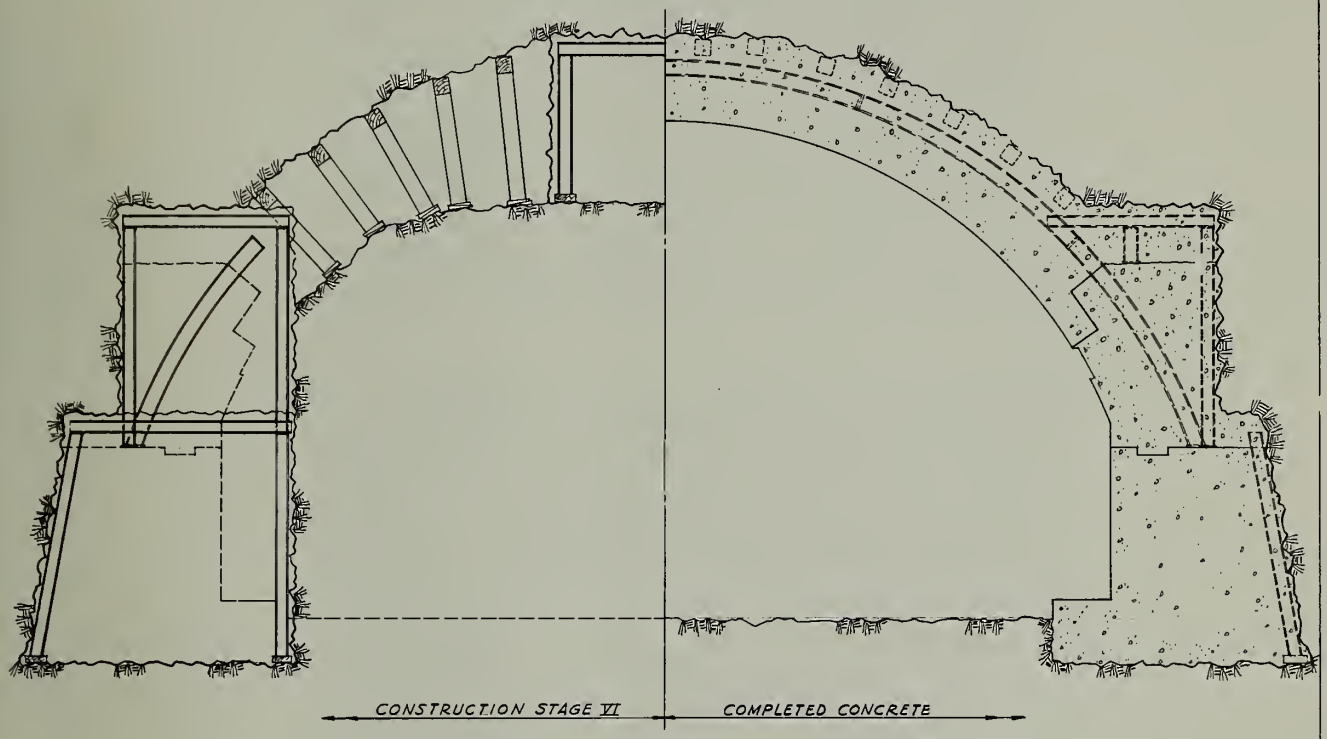
The soft, broken and extremely varied quality of rock in this vicinity predicts that it would probably be disastrous to attempt to construct a large tunnel by the full-face method. Any large bore driven through this material, where loss of ground will have serious consequences in the form of surface disturbances, must necessarily be constructed by very careful mining methods. These methods must be such that the tunnel is excavated a small portion at a time and with great care that no large area is left unsupported for a significant period of time.

We submit with this report our concept of such a method for constructing a tunnel beneath Fillmore Hill.

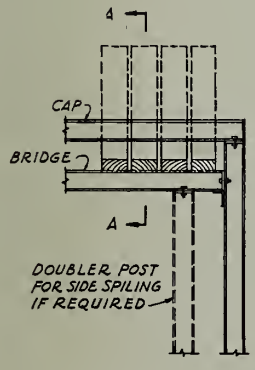
The method here detailed has been used as the basis for our estimate of cost. There are other possible methods which could be used to accomplish the same result. The one shown is safe, practical and conventional and suits the unsound nature of the rock which we believe will be encountered in this locality.

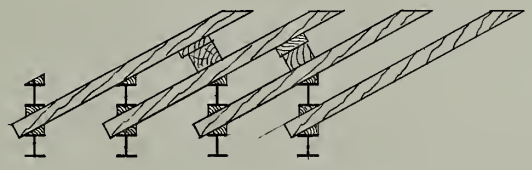
Plate 3, which is part of the report, illustrates the various stages which are proposed. Nothing radically new in mining techniques is shown here. The methods are those which have been used for more than a century in England and America for the driving of tunnels in soft ground and poor quality rock. Small chambers are excavated one at a time, taking every precaution that the ground is caught up and firmly held until it can be permanently supported with concrete. The sequential drawings are shown on Plate 3. Accompanying that plate is a page of explanation of the construction stages shown thereon.

Although the drawings have not shown complete details thereof, it is anticipated that liberal use will be made of spiling, forepoling, and breastboarding techniques. In areas adjacent to each portal it may be found advantageous to employ chemical soil stabilization treatment to help safeguard against ground settlement.



COMPOSITE CROSS SECTION





SECTION A-A

PROPOSED INSTALLATION OF SPILING WHERE REQUIRED

1884
2-4-66

TUNNEL PRACTICABILITY STUDIES ~ 1966
CITY AND COUNTY OF SAN FRANCISCO

PLATE 6

COST ESTIMATE

Determination of construction costs for the Fillmore Tunnel is not without its uncertainties. The brevity of time permitted only preliminary investigations and design assumptions. The size and timing of the many contracts which would be awarded in connection with a major freeway construction program could have a marked influence on the estimated cost of this particular job. The proposed Bay Area Rapid Transit subway program will undoubtedly be at its peak of activity during the same period, causing a heavy demand on labor within the Bay Area.

We have assumed that a separate contract will be awarded for the tunnel construction and that adequate work area will be available to the Contractor at both portals. Tunnelling operations have been carried out independently of adjoining construction with the exception that during the latter phases of work, joint use of approaches will be had by the several contractors involved. Wages have been used which reflect labor agreements as of June, 1966. Material costs have been taken at today's prices. All work has been prosecuted on a three shift per day, five day week basis. Although our estimate includes costs for both portal structures, we have arbitrarily deducted from the total cost that amount which we feel would be attributable to open cut and cut-and-cover construction beyond the tunnel.

The procedure followed in preparing the estimate was the same as would be used by a general contractor in bidding such work. Details of the various required operations, labor, materials, and equipment were analyzed and extended by means of an electronic computer using our firm's standard estimating program. A tentative bid proposal, showing costs for the various units of work required, is included herewith.

ESTIMATED CONTRACT PRICES FOR FILLMORE TUNNEL

	Quantity	Unit Costs	Total Cost
Webster Portal	Lump Sum	$1,846,578.00	$ 1,846,578.00
Scott Structure	Lump Sum	578,000.00	578,000.00
Drive Tunnels	3,260 LF	4,110.00	13,398,600.00
Line Tunnels	3,260 LF	2,090.00	6,813,400.00
Reinforcing Steel	6,575,000 Lb.	0.16	1,052,000.00
Waterproofing	1,400 SY	13.00	18,200.00
Suspended Ceiling	3,260 LF	212.00	691,120.00
Rubber Waterstop	7,300 LF	2.50	18,250.00
Miscellaneous Metal	Lump Sum	142,000.00	142,000.00
Drainage	Lump Sum	238,000.00	238,000.00
Water System	Lump Sum	26,000.00	26,000.00
Tile	Lump Sum	960,000.00	960,000.00
Lighting	Lump Sum	240,000.00	240,000.00
Ventilation	Lump Sum	655,000.00	655,000.00
Painting	Lump Sum	14,000.00	14,000.00
Roadbed	17,000 SY	10.80	193,320.00
Curbs & Walks	1,500 CY	65.00	97,500.00
		TOTAL BID	$26,981,968.00

TUNNEL VENTILATION

The length of the proposed driven tunnel is 1715 feet including end structures. The east portal will be at the east property line of Webster Street and the west end of the driven tunnel will be between Pierce Street and Scott Street. State Highway Department preliminary layouts indicate that cut-and-cover tunnel would be constructed from the end of the driven tunnel to the west property line of Scott Street. It will be necessary, therefore, to include the ventilation of this cut-and-cover portion of the underground structure with the ventilation of the driven tunnel. Thus the combination of driven tunnel and cut-and-cover section is estimated to extend from approximately station 550+00 to slightly beyond 570+00 or 2,000 feet.

European standards of vehicular tunnel ventilation have required from 50 to 100 cfm per traffic lane per linear foot of tunnel, dependent upon its length and particular circumstances. American practice has usually exceeded these amounts, running as high as 275 cfm per foot of two-lane tunnel on an upgrade, where traffic would be accelerated, and decreased to 150 cfm on level grades.

In view of the fact that ventilation of these two vehicular tunnels will be assisted by the prevailing westerly winds and that in each of the tunnels all four lanes will be traveling in one direction, an allowance of 115 cfm per traffic lane per foot of tunnel is considered to be an adequate provision. The full length of the tunnel is almost level, with abrupt changes in grade at each end, outside of the portals.

Studies were made of the feasibility of combined supply and exhaust ventilation system, fresh air supply only similar to the San Francisco Broadway Tunnel and an exhaust system. Evaluation was made of the

necessity for ventilation buildings at both ends of the twin tubes. The system of exhaust ventilation only through a single ventilation building at the east end was selected for reasons of economy, feasibility and the further desirable feature that the prevailing winds would carry the exhausted fumes over a freeway area and not into a residential section.

Studies were made of comparison between conventional centrifugal blowers and axial vane fans from the standpoint of suitability, cost, and noise nuisance. Axial vane blowers have been selected as being more economical and best adapted to the available space in the ventilation building. The axial flow fans furthermore permit more direct passage of the exhaust, reducing pressure loss in the elbows and constrictions required by the use of conventional centrifugal fans.

It is anticipated that ventilation requirements would be at a peak during the commuter hours of 7 to 9 a.m. and 4 to 6 p.m., dropping off to zero ventilation requirement during the early hours of the morning. An estimated 25% of total capacity was considered to be conservative operation requirement of the system during a 24-hour period. In the circumstance when a large number of vehicles in the Eastbound tube desire to enter the two-lane ramp heading for downtown San Francisco, just beyond the east portal of the tunnel, backed-up traffic could be stalled in the tunnel due to congestion at the entrance to the ramp. This situation would produce the heaviest demand on the exhaust system.

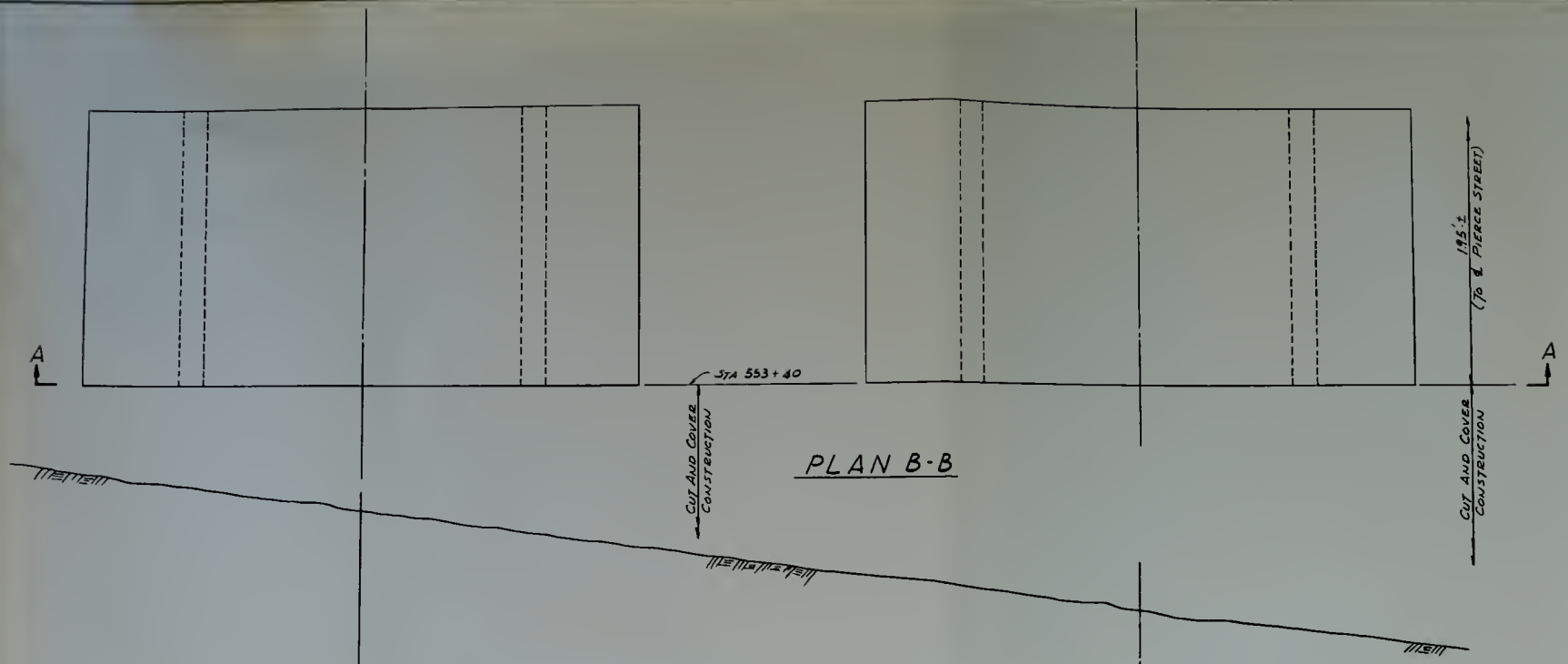
In order to provide flexibility in the operation and maintenance of the fans, consideration was given to a choice between two fans, each with two-speed motors, or four single speed fans. The latter was believed to provide greater flexibility for operational maintenance in view of the fact that loss of one of the fans in the former choice would reduce the

system to a maximum of 50% of capacity. Dampers would be provided ahead of each fan, interlocked with the driving motor so as to open at motor start and close at motor shut off. These would be a shutter type damper due to the large diameter of the throat of the blower.

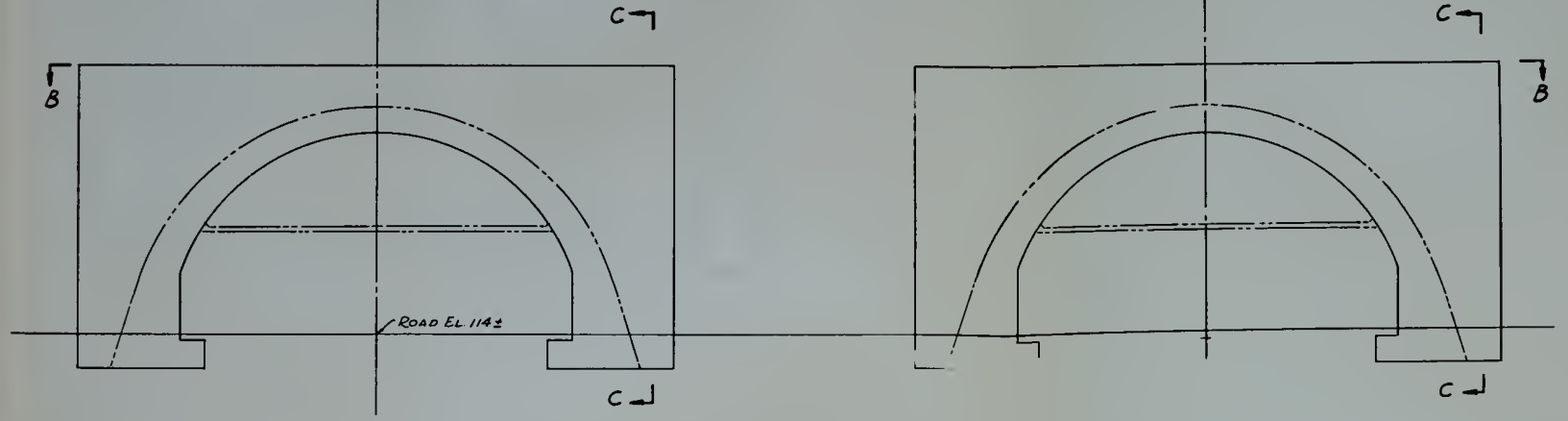
Automatic control of fan operation would be actuated by CO analyzers integrated with the system. Flow to the analyzers would be provided from five intakes in each of the tunnel ceilings and would register on the control board, visually and through automatic recorders.

A main control board would be provided in the control room and contain the CO equipment referred to above, manual fan controls, tunnel lighting indicators and switches, plus traffic signal controls.

The general concept of the ventilation system has been illustrated on the drawings accompanying this report, and its cost has been included in the total cost of the project as discussed in another section of this report.

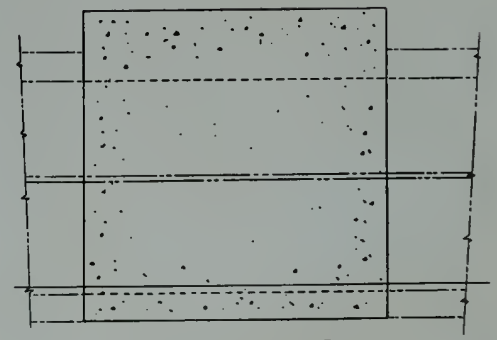


PLAN B-B



ELEVATION A-A

WEST PORTAL BLOCKS



SECTION C-C

REVISIONS	DESCRIPTION	BY	CK.	APP.	DATE

REVISIONS	DESCRIPTION	BY	CK.	APP.	DATE

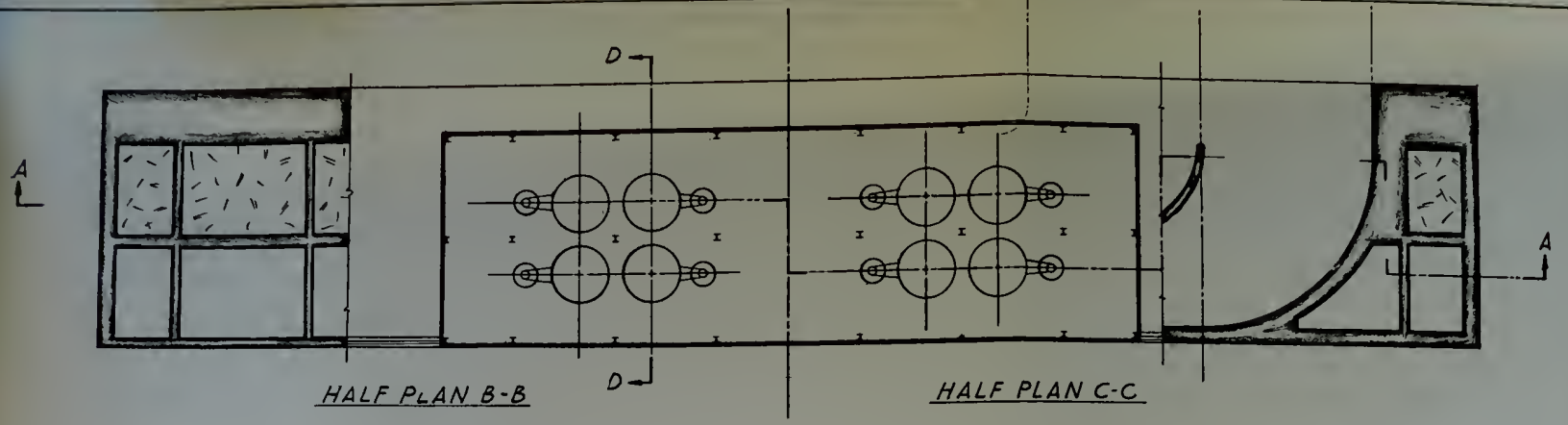
DRAWN BY	NAKAHURA	12-66
CHECKED		
APPROVED		

JACOBS ASSOCIATES
CONSTRUCTION ENGINEERS
500 SANSOME STREET
SAN FRANCISCO CALIFORNIA

TUNNEL PRACTICABILITY STUDIES - 1966
CITY AND COUNTY OF SAN FRANCISCO

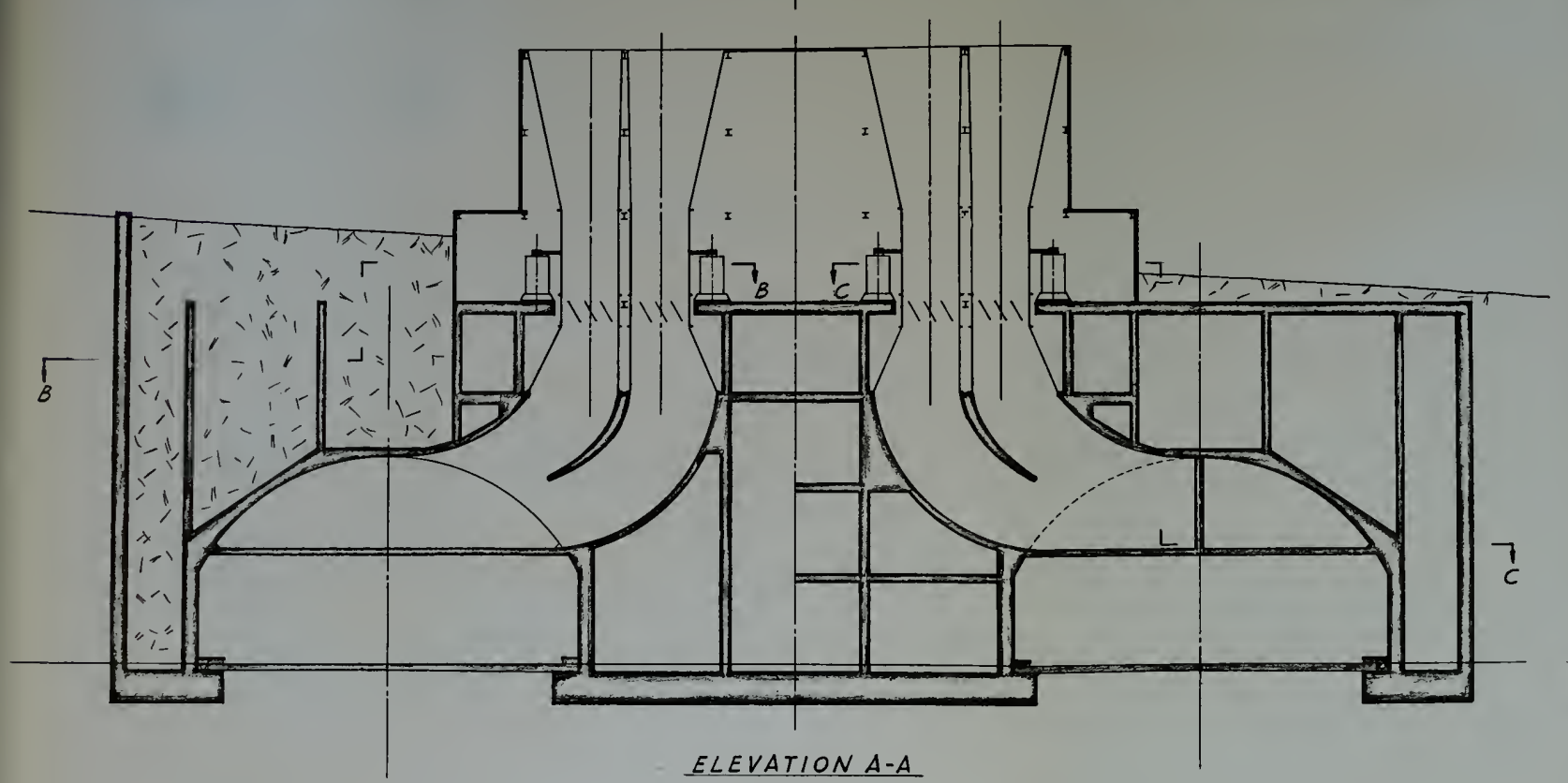
PLATE 7

SCALE	REV
SERIAL NUMBER	1884
DRAWING NUMBER	

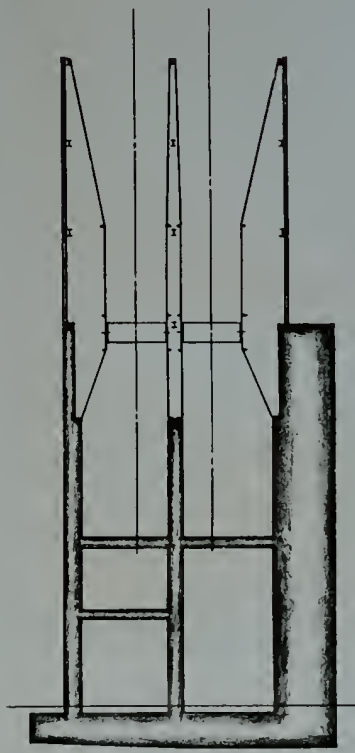


HALF PLAN B-B

HALF PLAN C-C



ELEVATION A-A



ELEVATION D-D

SECTIONS OF VENTILATION BUILDING

PLATE 8

DESCRIPTION	BY	CK.	APP.	DATE	DESCRIPTION	BY	CK.	APP.	DATE	DRAWN BY	NAKAMURA	8-4-66
										CHECKED		
										APPROVED		

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SAN FRANCISCO CALIFORNIA

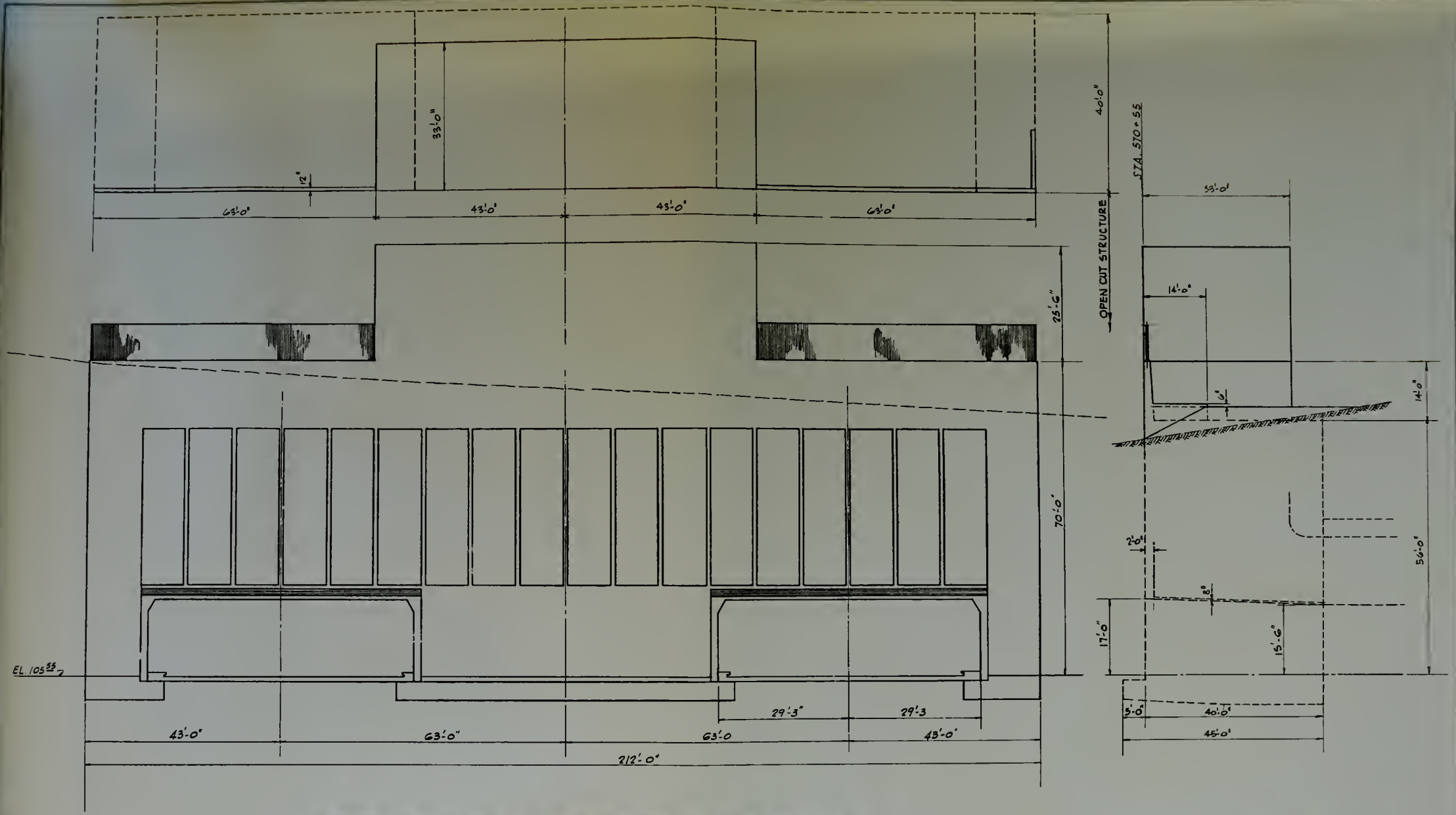
TUNNEL PRACTICABILITY STUDIES ~ 1966
CITY AND COUNTY OF SAN FRANCISCO

SCALE

REV

SERIAL NUMBER 1884

DRAWING NUMBER



EAST ELEVATION OF VENTILATION BUILDING.

PLATE 9

DESCRIPTION	BY	CK.	APP.	DATE

DESCRIPTION	BY	CK.	APP.	DATE

DRAWN BY SMART. 2-4-66
CHECKED
APPROVED

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TUNNEL PRACTICABILITY STUDIES - 1966
CITY AND COUNTY OF SAN FRANCISCO

SCALE
SERIAL NUMBER 1884
DRAWING NUMBER
REV

STANYAN HILL TUNNEL

Division of Highways alternative routes G and H contemplate twin bore tunnels beneath Stanyan Hill in the northeast corner of Golden Gate Park. To report upon the practicability of boring such a tunnel is one of the assignments of this report. The short period of time available for the making of this study and report has not permitted the allocation of as much effort to the Stanyan Tunnel as to the Fillmore Tunnel. Even while giving the solution of the Fillmore Hill problems first priority in accordance with instructions from the Director, we have given enough study to the proposed Stanyan Tunnel that we are prepared to present our opinions relative thereto.

Original testing of subsurface materials by the Division of Highways had consisted of a single bore hole put down in 1963. That hole was located somewhere near the midpoint of the proposed tunnel. Log of the hole indicated sand and soil materials to a depth below the grade of the tunnel. Ground reconnaisance within the Park, however, revealed an outcropping of Franciscan rock on top of the ridge across Stanyan Street from St. Mary's Hospital and approximately on the route of the proposed tunnel.

After the Drilling Contractor had finished making the exploratory borings in Fillmore Hill, he was asked to move to the Park and drill three holes from ground surface to top of rock, at locations specified. By the time he was starting this work, the deadline for completion of this report was fast approaching and time was not available to take core samples of the rock. The purpose of the three holes was to locate the depth of the rock surface

and thereby determine the amount of rock excavation which might be expected.

After studying the drill probings and visible rock outcroppings with reference to proposed tunnel route H2, we reach the conclusion that no more than half of the total length of the twin bores would encounter any rock at all. The South tunnel located on the downhill side of the formation will find the surface of what rock there is to be much lower than the corresponding surface in the North tunnel.

Total distance which could be constructed by tunnelling methods under Stanyan Hill is approximately 1,200 feet. We would expect that more than half of the total tunnelling in this stretch would be entirely in sand and soil. Most of the remainder will be through a mixed face of sand and rock.

Shield tunnelling techniques are probably adaptable to this tunnel. Blasting would be performed when rock is encountered. Some surface settlement will be unavoidable, but because of its uniformity, it should not be harmful to vegetation. Therefore, in this Park area, ground subsidence is not a serious consideration. The use of shield methods would result in a reduction of costs below those estimated for Fillmore Tunnel.

Time has not permitted the making of a detailed cost estimate for Stanyan Tunnel. We expect that a Stanyan Tunnel can be constructed considerably cheaper than a Fillmore Tunnel. The conditions are much less restrictive at Stanyan. A contractor can be permitted more freedom and the Engineer need not exercise the rigid controls which must be held over the constructor at Fillmore. Taking these considerations into account and based on judgment alone, we expect that a foot of Stanyan Tunnel will cost 65% to 85% of a similar foot of tunnel constructed under Fillmore

Hill. Based on the Fillmore estimate, this would give a cost range of $5,100 to $6,700 a foot of single bore under Stanyan Hill.

Even though the cost of a driven tunnel through Stanyan Hill may be somewhat lower than one through Fillmore Hill, we believe that underground excavation will prove to be less desirable than cut-and-cover construction. The most weighty argument against open cut construction probably is destruction of Park greenery. The substantial savings in cost which are probable to result from the cut-and-cover method should contain ample money to carefully remove, preserve and replant all existing trees which the Park Commission desires to save.

HYDE HILL TUNNEL

An investigation into the practicability of tunnelling under Bay Street where it crosses Hyde Street was mentioned in the original terms of reference pertaining to this study. The Hyde Tunnel was to have been studied if time was available and if so instructed by the Director.

During the first three weeks in January all our available technical manpower was committed to gathering and analyzing the core boring information from Fillmore Hill and taking a quick probing survey of Stanyan Hill. There was no time left to make subsurface investigations at Hyde, the location considered to be the least in need of study.

The profile to be followed by the roadbed beneath Bay Street will, of course, determine the height of cover above the roof of the tunnel. The one profile which we have inspected for proposed route F2 Modified affords a very low average cover above a comparatively short length of bored tunnel. We do not believe it to be practicable to construct a driven tunnel for this short a distance under this very low cover.

AQUATIC FREEWAY PROPOSAL

Golden Gate Aquatic Freeway is the name given a plan which has been proposed by Design Consultants Engineering Corporation, a private engineering firm. We have been asked by the Director to review it and comment upon it in this report.

The engineering information we would have wished to have in order to more fully evaluate this proposal has not been obtainable within the period of our assignment. Perhaps much of it does not exist. We were handed a copy of the PRELIMINARY PROPOSAL, a 16-page report which had been submitted to the City by Mr. Conrad Douglas, President of Design Consultants, on November 9, 1965. This book contains free-hand sketches, conceptual illustrations and two map reproductions. There are no engineering drawings included nor does it contain technical information from which to make an evaluation.

On Wednesday, January 26th, two of our engineering representatives attended an evening meeting of the Golden Gate Chapter of the California Society of Professional Engineers at which Mr. Douglas spoke in behalf of his Aquatic Freeway scheme. We have also visited the San Francisco office of Design Consultants Engineering Corporation in an effort to obtain additional engineering drawings and technical data which may be of assistance to us in our evaluation of their proposal. The only material that we have received from the Author Firm consists of some worksheet sketches, not to scale, and a copy of their own cost estimate.

In order to have some definite dimensional information for use in estimating of quantities, we have drawn our own interpretation of a cross

section of the proposed float-in-place structure. Please refer to our Plate No. 11. Of great significance is the contrast in size between the Aquatic Freeway structure and the Bay Area Rapid Transit Tube structure, the outline of which is shown dotted to scale within the Freeway structure drawing. In a comparison of weights, the freeway structure would weigh 4.6 times as much as the BART Tube section per foot of length. This provides a basis for comparison of the probable cost of marine handling and laying of sections.

We have recently had the experience of making a Contractor's estimate for construction of the Rapid Transit Tube. To the best of our knowledge there exists no private dry dock facilities in the Bay Area which could handle a precast concrete structure of this size.

The principle of precasting concrete sections in a dry dock, floating them to location, and sinking them into position is a feasible method of construction. This system has been used for years in the building of subaqueous tunnels. We know of no similar structure comparable in size to this one. For that reason, we caution against unforeseen problems which will arise from the pure immensity of the undertaking.

The designers of the scheme have submitted their estimate of cost of the project which totals approximately $67,000,000.00 for the four miles of construction or an average of $3,200 a foot. We feel that this cost is unrealistically low. The approximate cost of the Bay Tube crossing, based on the bid of the successful contractor, was approximately $4,700.00 a foot A comparison of the respective sizes of the two structures should cause considerable doubt that the larger structure could be built for less money than the smaller one. Our cost assessment is based upon an analysis of the quantities in a single unit of a typical float-in-place section. We give

below a list of the various costs which must be accounted for in the building of one of those sections. Opposite each cost classification is the amount in dollars per linear foot of completed freeway construction. We believe the amounts shown are those at which the work can be contracted at today's market. The figures are based to some extent upon recent Bay Tube quotations and have been weighed against past experience.

Dredging	$ 330.
Foundation Course	400.
Precast Concrete Shell	3,480.
Reinforcing Steel	1,095.
Waterstops and Waterproofing	355.
Bulkheads	600.
Gaskets and Couplings	400.
Towing and Placing	800.
Concrete Ballast	510.
Electric Lighting	180.
Ventilation	600.
Curbs and Walks	35.
Miscellaneous Piping	50.
Tile Work	558.
Protective Riprap	476.
Total Cost Per Foot	$9,869.

No allowance has been made in these costs for removal or replacement of piers, wharves or other existing marine or waterfront structures.

It is our recommendation that, for present discussions, the float-in-place portion of an Aquatic Freeway be anticipated to cost $10,000 a foot when completed. Because of the preliminary nature of this assessment, that figure may increase 15% or decrease 10% after development of more definite information.

Before considering a partially submerged offshore Freeway structure, we suggest that expert advice be obtained in the field of oceanography regarding

the possible affects of tidal waves upon such a structure in San Francisco Bay. Within the past several years tidal waves along the coast of California have caused surges of water within the San Francisco Bay which have done severe damage to marinas and floating structures along the waterfront. Evidence is that the water surface rises a considerable distance above normal conditions when such a tidal wave occurs. To avoid the possibility of the destruction of a semi-submerged structure as is here proposed it will be necessary, we believe, for it to be of such weight that it will be non-buoyant even if the surface water rises completely over its top.

As the freeway continues northward past the Marina, why go to the great expense of offshore construction between St. Francis Yacht Club and Golden Gate Bridge? It would seem to be more economical to connect with the existing bridge approaches in the vicinity of the Palace of Fine Arts, thereby saving a mile or more of expensive construction.

An offshore seawall from the Yacht Harbor to Crissy Field will leave a long, narrow sliver of water which will have little value for recreational purposes. The authors speak of creating useful land within this area. The result will be more permanent filling-in of the Bay, an activity which meets with disfavor in many places today.

The entire length of the freeway from Broadway to Golden Gate Bridge will be completely within a tunnel, most of it subaqueous. This is contrary to policy which we believe has been agreed upon between the City and State that no more than 50% of any freeway shall be underground. It will also create a psychological barrier against its use by a certain segment of the populace to whom the contemplation of driving through a subaqueous tunnel will forever be intolerable.

AN ALTERNATIVE

Should the driven tunnels, reviewed as to practicability in the foregoing report, be rejected because of cost, consideration might be given to an alternative alignment. A study has been made of the feasibility of constructing a double decked cut-and-cover tunnel under Fell Street within the property lines bounding the street. The width of the structure is such as to place soldier piles and lagging, necessary for supporting the excavation, very close to the property lines. This results in difficult construction conditions, but not to an unreasonable degree.

Use of that alignment would result not only in preventing destruction of the dwellings in the three blocks between Webster and Pierce Streets, but also would save from demolition another two blocks of residences and commercial enterprises. The latter area is bounded by Fell and Oak Streets between Pierce and Divisadero Streets, a total of two square blocks. It would reduce the number of displaced families by a substantial number and thus provide even greater sociological benefits than the driven tunnel.

This alignment should cost considerably less than the driven tunnels and could be constructed in less time. It is true that, due to the width of the structure as presently proposed, it would be somewhat more expensive to locate it in Fell Street, rather than midway between Fell and Oak Streets, but sociological factors may outweigh that differential in cost. The on and off ramps at Divisadero Street could be constructed similarly to those shown in the Division of Highways alternatives. Added structure would be required at the complex interchange at the east end of the tunnel between Webster and Laguna Streets, although the additional cost should not be an unreasonable amount.

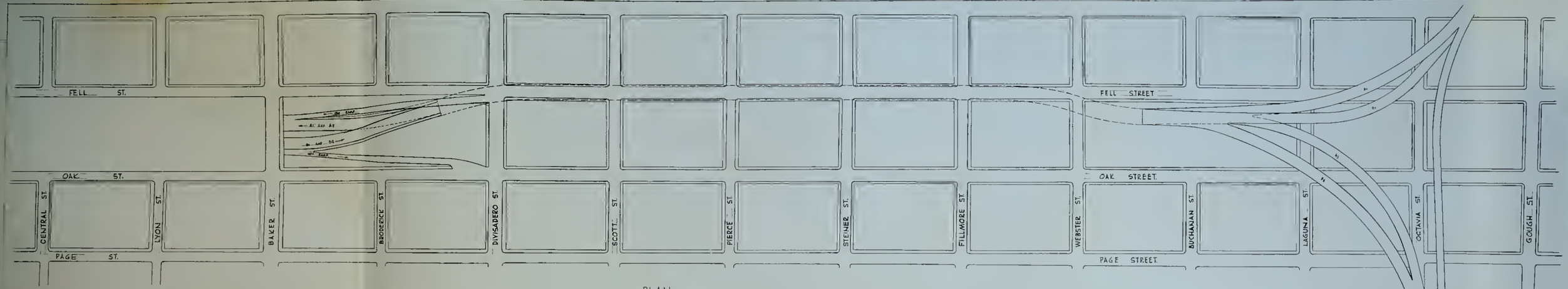
Construction on this alignment would require the closure of alternate blocks on Fell Street during the

periods required to place soldier piles and support members. The street would be reopened after temporary wood decking had been placed so that construction could be continued below street level. Access to the closed areas for Fire Department equipment would thus never be farther than one-half block away. Most of the inconvenience to residents of Fell Street would be limited to the short period required for the street preparation described above.

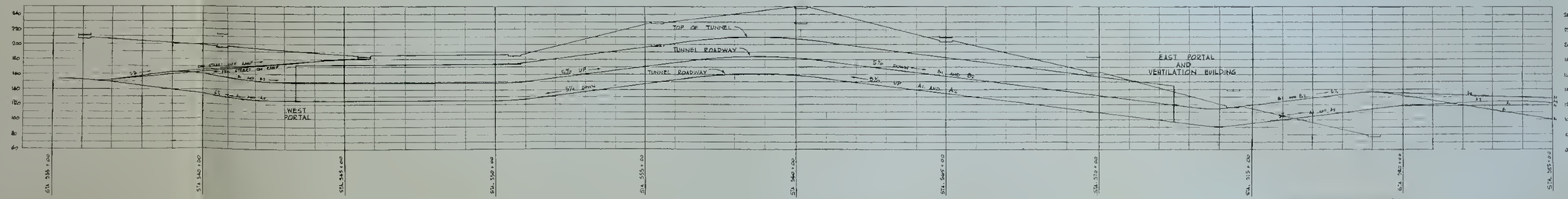
Ventilation requirements would be somewhat greater for the cut-and-cover tunnel in this alignment than for the combination of driven tunnel and cut-and-cover tunnel contemplated between Webster and Scott because of the 900 feet of additional length. The tunnel on this alignment would reach a crest in the vicinity of Steiner Street. This suggests the desirability of a single ventilation building near to that crest. It would necessarily have to be constructed off the street on either the north or south side of Fell Street, requiring demolition of some residences.

The reduced drawing attached hereto shows the suggested realignment of the double-decked tunnel structure in plan, with a corresponding profile below. Horizontal and verticle curvatures are indicated thereon. Similarly, ramp grades for connection to the existing freeway at the east end as well as on and off ramps in the vicinity of Divisadero Street have been shown schematically. These are believed to be in conformance with Division of Highways standards.

In view of the urgent need for usable freeway extensions in San Francisco, the time saving presented by this alignment, the probable saving in cost, and the preservation of additional dwellings may make it more attractive than twin tunnels driven through the hill. It is,therefore, submitted for consideration as an alternative procedure to accomplish the objective of freeway extension with a minimum displacement of families in this severly congested area.



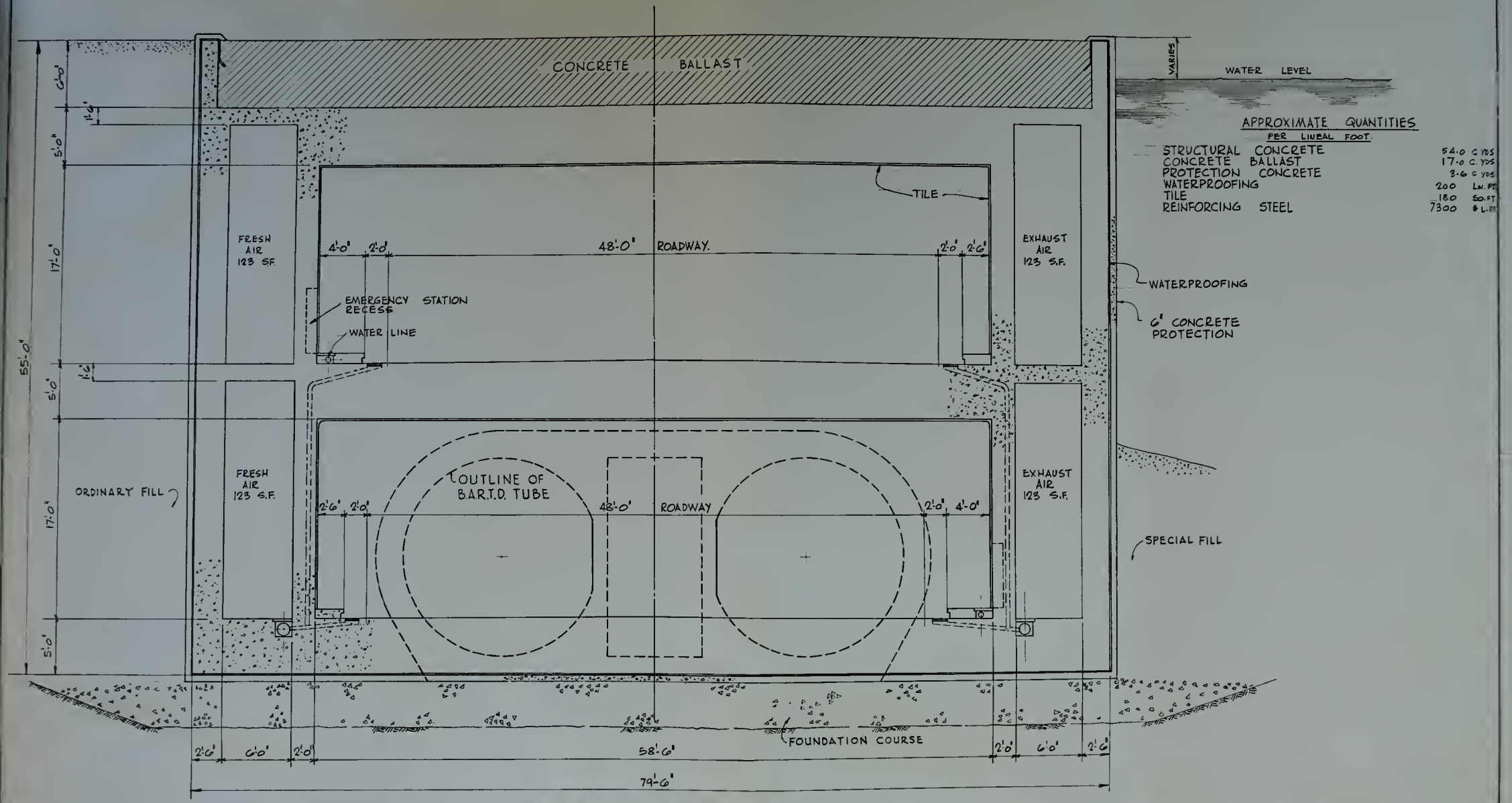
PLAN



PROFILE

ALTERNATIVE ALIGNMENT FOR FILLMORE TUNNEL

PLATE 10



APPROXIMATE QUANTITIES
PER LINEAL FOOT.

STRUCTURAL CONCRETE	54.0	C YDS
CONCRETE BALLAST	17.0	C. YDS
PROTECTION CONCRETE	3.6	C YDS
WATERPROOFING	200	LN. FT
TILE	180	SQ. FT
REINFORCING STEEL	7300	# L. FT

TYPICAL SECTION OF AQUATIC FREEWAY.

PLATE 11

DESCRIPTION	BY	CK.	APP.	DATE

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REVISIONS

DRAWN BY J.S. 2-6-66
CHECKED
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TUNNEL PRACTICABILITY STUDIES - 1966
CITY AND COUNTY OF SAN FRANCISCO

SCALE
SERIAL NUMBER 1884
DRAWING NUMBER
REV.

GOLDEN GATE
AQUATIC FREEWAY
HYDE STREET TUNNEL
STANYAN HILL TUNNEL
FILLMORE HILL TUNNEL
PRESIDIO MILITARY RESERVATION
Fort Scott
CRISSY FIELD
Marina District
Western Addition
Pacific Heights
Chinatown
Nob Hill
North Beach
Rincon Point
SAN FRANCISCO
PARK
Mission District
Richmond District
Lone Mtn
Mountain Lake
Lobos Creek
Mt Sutro
Central Basin
China Basin
PLATE 12

APPENDIX

REPORT OF MR. ROGER RHOADES
CONSULTING GEOLOGIST

ROGER RHOADES
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February 2, 1966

Mr. J. Donovan Jacobs
Jacobs Associates, Construction Engineers
500 Sansome Street
San Francisco, California

Dear Mr. Jacobs:

I have collaborated with you during the last few weeks in your studies of proposed tunnels beneath Fillmore and Stanyan Hills. My role was to assess the geological conditions that these tunnels would encounter. I have discussed my conclusions with you in detail; and you have asked that I summarize these conclusions briefly in writing. I do so in the following paragraphs.

The two areas expose very few rock outcrops. In the Stanyan Hill area - the northeast end of Golden Gate Park - bedrock crops out opposite St. Mary's Hospital and at the horseshoe pits. Elsewhere this part of the Park is covered by sand and soil, presumably imported. Alamo Park near the Fillmore Hill tunnel line is also covered by soil. The school adjacent to Alamo Park is probably built on bedrock, and the parts of the school yard not covered by asphalt and concrete show, here and there, areas of rocky soil indicating that bedrock is not far beneath. Elsewhere, the tunnel lines and adjacent areas are covered by buildings, sidewalks and streets.

You have drilled eleven holes - eight on Fillmore Hill and three on Stanyan Street. I observed these holes as they were drilled and subsequently examined the cores, samples and inspectors' records. My conclusions, which follow, are based largely upon these borings, upon my knowledge of the geological formations involved, and upon the known construction histories of tunnels through these formations.

The hills of San Francisco are generally pinnacles of bedrock jutting upwards through dune sands and residual soil which surround them. The bedrock, although harder than the soils and sands that surround them, is frequently weathered and weakened to considerable depths. The bedrock along these tunnel lines is the Franciscan formation, and consists mainly of sandstones, shales, cherts, and igneous rocks which are usually partially or entirely altered to serpentine. The bedrock pinnacles frequently have steep slopes, with abrupt transitions to the surrounding soils and the sand that has drifted against them.

The sandstones of the Franciscan formation, when unweathered or otherwise weakened, are hard and siliceous, but brittle, and frequently closely jointed.

The shales, when unweathered or otherwise weakened, are firm and siliceous; but they are susceptible to weakening as noted below.

The cherts, when unweathered or otherwise altered, are very hard and brittle, and usually closely jointed.

The igneous rocks, when unweathered or otherwise weakened, are hard and competent; but they are usually serpentinized to a greater or lesser degree.

Serpentine is a greenish rock, characteristically traversed by smooth shear planes, and host to internal stresses causing high expansive pressures when excavated.

The Franciscan formation has been folded, contorted, faulted and sheared. These disturbances have caused the development of joints, shear planes and gouge zones, and have caused the strata to lie in complicated and contorted attitudes. Weathering to various depths has further weakened the outer portions of the foundations.

The borings indicate that Fillmore Hill contains all of the aforementioned materials - sandstone, shale, chert, serpentine, igneous rock, and fault gouge. These materials vary from fresh to highly weathered. The steep dips, contortions, shears and faults prevent correlation between borings.

The complicated contortions and disruptions of the strata would cause abrupt changes in rock type in a tunnel. At any given station, different rock materials could be exposed in the back, walls and invert of a tunnel.

The sandstones, being closely jointed, will require close support and lagging; but they will not be "heavy" if quickly caught up and held in place.

The shales if unaltered, will excavate easily and in a smaller tunnel would cause little trouble. But they are not a strong rock, and in a tunnel of this size they would require close support. However, the shales are very susceptible to alteration, and will soften if saturated and then could become "heavy", and require more support. Moreover, the shales are the rock unit most commonly sheared and faulted; the resulting gouge would be both heavy and flowing if saturated, and saturation is expectable.

The cherts would behave much like the sandstones.

The serpentine would swell and squeeze; the partially serpentinized igneous rock would act similarly but to a lesser degree - the degree depending on the degree of serpentinization.

I am not greatly concerned with the bearing competence of these materials for footings except where softened shale or gouge should occur in the footing areas. The latter materials would have low bearing capacities. The serpentines would not consolidate under the footings, but rather would tend to heave.

I do not believe that ground water would be a problem. The gouge zones and softer shales may be saturated and cause a "mucky" invert. Rain water seeping downward through the shallow cover may require attention, but will be small in amount, and will be important mainly in softening susceptible rock types.

The portals would require special attention. Rather deep cuts through overburden would be required to gain access to rock, and the rock first encountered will be weathered, and the cover shallow.

In my opinion the geological problems confronting a Fillmore Hill Tunnel would be mainly in the excavation phase. Excavation

would be difficult and would require careful application of special tunneling procedures. In your report you are suggesting a sequence of procedures. I am confident that the tunneling could be accomplished without serious trouble underground, or material subsidence above ground, if these procedures - or some other equally conservative procedures - were used by a knowledgeable contractor. However, if a contractor should approach his excavation less cautiously he would have serious troubles underground, and damaging surface subsidence would be expectable. I think that after the excavation was accomplished, with appropriate temporary supports, the installation of permanent lining and appurtenances should be only a matter of routine design and construction.

Most of the above comments concerning Fillmore Hill probably apply also to Stanyan Hill. However, the lateral extent of the rock exposed in outcrop and in the middle boring may not be great. The length of this tunnel and the approach cuts, and the location of the portals, remain uncertain.

Sincerely yours,

Roger Rhoades

Roger Rhoades

RR:rb